Fusing a Crosscutting Concept, Science Practice, and a Disciplinary Core Idea in Single Learning Progression

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Abstract: In this paper, we report on a learning progression that fuses systemic reasoning (cross-cutting concept) and ecology (core idea) in what we call "ecological systemic reasoning". We used semi-structured interviews with 44 students (1st through 4th grades). The results revealed that a hypothetical learning progression begins with anthropomorphic reasoning as the lower anchor and ends with complex causal reasoning as the upper anchor for students in this age.

Project Background

Recently, learning progressions ("descriptions of successively more sophisticated ways of thinking about a topic that can follow one another as children learn about and investigate a topic over a broad span of time", NRC, 2007, p. 214) have been used to examine how students learn over time. For example, Songer et al. (2009) describe an empirically based, fused learning progression for ecology and scientific explanations used to guide the development of curricula and assessment items for elementary students (grades 4th – 6th). Although this fusion approach gives important insights into students' developing abilities to fuse disciplinary core ideas and a science practice, they did not take into consideration a holistic approach that fuses the systems thinking as a cross cutting concept with ecology as a disciplinary core idea as students explain phenomena (a science practice). Grotzer and Bell (2003) showed that 3rd graders can learn to reason in more sophisticated ways when taught explicitly about causal reasoning. However, many students still lagged behind in understanding the global picture of species interdependency. Therefore, more empirical work is required to understand how younger students reason about species interdependency in ecosystems, specifically before formal instruction. This study builds on the literature in two ways: (1) it explores students' reasoning of ecosystems before instruction and (2) it uses the systemic reasoning approach to identify a hypothetical learning progression for students' systemic reasoning in domain specific content.

Chandler and Boutilier (1992) proposed a hypothetical reasoning model that applies to open systems, "dynamic system reasoning." They proposed four properties for systemic reasoning: (1) systemic synthesis: i.e., understanding that a change in one component affects others; (2) systemic analysis: i.e., there are critical elements (like water molecules or sun) that are essential for the system (e.g., hydrologic system) to work and they are different from incidental elements (e.g., storms); (3) circular connectivity: which is the opposite of systemic synthesis where the students are asked to make the system from the independent elements; (4) dynamic recycling: i.e. molecules do not exit from the system but instead keep circulating in it. When examining whether students' systems reasoning was ontologically different from Piaget's formal operational reasoning or whether it is a kind of reasoning that develops at the "heels of Piaget's formal operational reasoning," they found out that there were significant statistical differences between the two kinds of reasoning. That is, students' performance on the dynamic system reasoning task was a separate "ontogenic" category different from that of Piaget's. Building on Chandler and Boutilier's framework, we have adopted two categories of systemic reasoning (circular connectivity and systemic synthesis) and developed a hypothetical learning progression for those two categories. Note, that we also studied the learning progression for the other two categories, but due to space limitations, we focus on those two categories because they required students to utilize two opposite skills: one of constructing the ecosystem from individual components, and one of analyzing the components a pre-existing system. To organize the study, we pose the following research question:

What are the patterns in 1st to 4th grade students' systems reasoning with regard to constructing a complex food web (circular connectivity), and with regard to relating the effect of changing one population on others in the food web (systemic synthesis)?

Method and Data Analysis

The participants in this study were 44 1st through 4th grade students in a suburban Midwestern school. We used semi-structured interviews to probe students' ideas about each of the four systemic reasoning categories. All interviews were transcribed verbatim and then the transcripts were checked against the recording. We had an iterative process of several rounds of coding: we first started by looking at students' answers, took a small sample and used constant comparative method (Strauss & Corbin, 1998) to derive general codes about students reasoning in the system. After deriving initial codes, we went back to the data and re-coded students answers accordingly and then went back to refine our codes, in an iterative process consistent with the learning progression approach (Collins et al., 2004).

Findings and Implications

The results of this study revealed 5 levels in the hypothetical learning progression for systemic reasoning: the lower anchor (level 1) was anthropomorphic reasoning where students where students projected human characteristics or personal liking to their reasoning with no reference to any external mechanism or cause. Level 1.5 was anthropocentric reasoning where students related their choices and reasoning to what they were used to in real life: they still did not utilize an external mechanism that considered underlying causes of the event, but at the same time, they did not relate the reasoning to personal liking of human characteristics. Instead they reasoned from their common everyday experiences. Level 2 was simple causal reasoning where students identified one external factor that was influenced by the change. Level 3 was semi-complex causal reasoning which took into account more than one external factor affecting the phenomena, but at the same time did not recognize how all populations influence each other. The upper anchor, level 4, was one where students recognized the network of relations in the system.

The results of this study revealed that many students could reason about ecosystems before exposed to formal instruction. The concentration on shelter as a condition to construct an environment concurs with Lehrer and Schauble's (2012) finding that elementary students' conception of ecology in general starts with anthropomorphic reasoning and develops to consider shelter as an important factor and moves on to add factors reasoning about the influence of changing one population on all populations of the ecosystem. Moreover, similar kinds of reasoning to this study were found by Leech et al. (1996), who found that even older students are more likely to consider effects on direct populations than those of indirect populations suggesting that lower elementary students reason in similar ways to middle and high school students. This means that with proper instructional materials, lower elementary students are likely capable of thinking at a systemic level and capable of appreciating the complexity of interactions in the ecosystems. This is supported by research that showed that proper software models (Eilam, 2012) together with organized instruction allows successful learning of systemic reasoning in the context of ecosystems.

This study is important for two reasons: first, it fuses a disciplinary core idea and a crosscutting concept to develop a unified learning progression of how students reason (a science practice) about ecology; and second, it continues the conversation of how learning progressions need to be revised in an iterative process that best captures students reasoning so that we can design effective instruction that fosters desired learning goals for our students. It is important to start conversations about the criteria of developing learning progression and what can be fused or teased apart because this renders learning progression research more coherent and directs future research agenda in the field.

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